PARASITIC PLANTS: A CuRe FOR WHAT AILS THEE

A host plant surface-localized immune receptor confers recognition of a parasitic plant

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Parasitic plants can dramatically change ecosystems and represent a serious biological risk to agriculture by attacking crops of high economic importance. A highly conserved part of the plant immune system is the recognition of Microbe-Associated Molecular Patterns (MAMPs) by plasma membrane Pattern Recognition Receptors (PRRs) that upon activation initiate an effective immune response (*1*). Whether parasitic plants are also sensed as foes by PRRs was until now unknown. In this issue of *Science*, Hegenauer *et al.* report for the first time the identification of a canonical PRR that is required for responsiveness to a MAMP-like molecule from the parasitic plant *Cuscuta reflexa* and protects plants against parasitic attack. This finding opens the possibility of new biotechnological applications leading to sustainable strategies for crop protection against devastating parasitic plants.

The ability of plants to capture energy from sunlight makes them attractive targets for parasitic organisms looking for hosts rich in carbohydrates, nutrients and water. Not surprisingly, a litany of parasitic organisms including microbes, insects, nematodes and parasitic plants are able to infect plants and use them as their primary source of nutrition. The biological threat mounted by parasitic organisms can cause devastating agricultural loses and dramatically influence natural ecosystems, jeopardizing ecological diversity if they take hold. Parasitic plants are estimated to cost billions of dollars a year in crop yield loss and affect crops across all five continents including Africa (*2*). Seeds of parasitic plants can survive in soil for an extensive period but after germination they must find an appropriate host plant within few days. Plants of the genus *Striga* and *Cuscuta* have developed very refined strategies to perceive host plants by sensing nearby host-derived molecules, a strategy that dramatically increases their chance of a successful infection (*2*). Once in contact with the host, the survival of the parasitic plant depends on the rapid formation of haustoria that penetrate the host cell wall and siphon nutrients directly from vascular tissue (*3*). Haustoria formation is a common evolutionary virulent strategy employed by multiple parasites including fungi and oomycetes. Therefore, the virulent strategy of plant parasites seem to share some commonalities with parasitic microbes, raising the possibility that plants also have evolved common strategies of resistance against both plant and microbial parasites.

Plant immunity against parasitic microbes partially relies on the ability to recognize infectious non-self molecules through the perception of microbial MAMPs by host PRRs and rapidly activate immunity (*1*). To study if similar strategies exist underlying resistance of plants to parasitic plants, Hegenauer *et al.* exploited the interaction between the stem plant parasite *C. reflexa* and the cultivated tomato, which is resistant to this parasite (*4*). The authors found that tomatoes respond to *C. reflexa* extracts with immune phenotypes similar to the ones typically associated with perception of MAMPs, indicating that *C. reflexa* produces a MAMP-like molecule (hereafter called Cuscuta factor). To identify the source of perception associated with the putative Cuscuta factor, Hegenauer *et al.* screened for lines lacking responsiveness to *C. reflexa* extracts in a tomato collection. The authors found that perception of the Cuscuta factor depends on a canonical PRR that is constitutively associated with SlSOBIR-type protein kinases The authors renamed this receptor as *Cuscuta* Receptor 1 (CuRe1), which becomes the first surface-localized receptor found to recognize a parasitic plant.

The authors could not define the exact nature of the Cuscuta factor, but it appears to be a small, potentially O-glycosylated peptide that is associated with and might be a widespread structural component of the cell wall of *C. reflexa*. This Cuscuta factor is present in all *Cuscuta* species tested but absent from parasitic plants outside this genus, which contrasts with the current paradigm that MAMPs are widely conserved amongst microbes (*6*). In this sense, it is tempting to speculate that the Cuscuta factor might be a parasitic cell wall secondary metabolite required for virulence or a common cell wall protein with an specific post-translational modification. The rather narrow distribution spectrum of the Cuscuta factor likely reflects the elevated evolutionary pressure that plants encounter for perceiving parasitic plants as non-hosts without perceiving oneself.

Recent studies have revealed that PRRs can work effectively across plant species (*7, 8*). To evaluate the potential of CuRe1 to protect susceptible plants against the attack of *C. reflexa*, the authors transformed CuRe1 into closely and distantly related susceptible plants. CuRe1-transformed lines restored sensitivity to the Cuscuta factor and were more resistance to *C. reflexa* attack. Thus, CuRe1 has the potential to protect crop plants against infestation by this parasite. It is noteworthy that Hegenauer *et al.* observed that cultivated tomato has an additional mechanism of resistance against *C. reflexa* apart from CuRe1. In accordance, multiple layers of incompatibility between host plants and *Striga* species have been reported (*9*).In microbes, haustoria serve as secretion and translocation sites for virulent proteins

known as effectors that are devoted to promote pathogenesis, and at the same time can be recognized intracellularly by resistance (R) proteins, re-activating immunity into its strongest way (*1*). Plant parasites and host plants also exchange mobile molecules through the haustorium (*3*, *4*) and resistance to *Striga* relies on a cytoplasmic host R proteins (*10*). It is therefore conceivable that parasitic plants secrete, through the haustoria, virulent effector-like proteins as microbes do, in an attempt to promote parasitic growth. Effectors, as in the case of microbes, can in turn be recognized by intracellular host R proteins creating multiple layers of resistance against parasitic plants.

The identification of CuRe1 represents a major breakthrough in understanding the common strategies used by plants to sense danger from multiple origins. This work greatly advances our understanding of the mechanisms controlling plant resistance to parasitic plants while opening up new exciting questions in an emerging field. What is the nature of the Cuscuta factor? Are other parasitic plants perceived by PRRs? Do parasitic plants inject effectors into their host and do R proteins recognize these effectors as in the case of parasitic microbes? Importantly, interfamily transfer of CuRe1 emerges as a feasible strategy for crop protection while standardized bioengineering approaches and gene editing by CRISPR-Cas9 will accelerate the engineering of receptors with novel ligand specificities on demand (*11*). This is the beginning of an exciting time that will allow us to understand the intracellular dialog during parasitic plant-plant associations with broad application in agriculture.

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